

## The Relationship Between Cocoon Weight and Prepupal Weight in *Megachile rotundata* (Hymenoptera: Megachilidae)<sup>1</sup>

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The utilization of energy and nutrients by organisms can be viewed as a problem in the efficient allocation of limited resources to the various processes and characteristics necessary for survival and reproduction. In a broad sense, a trade-off exists between survival and reproduction (Calow, 1977) such that requisites directed to one process are generally unavailable to, and prevent the maximization of, the other. Among some species of bees, one characteristic linked to survival is the cocoon. Cocoons are thought to improve the chances of survival to the adult stage by maintaining a favorable environment for continued development, and by affording protection from enemies (Stephen et al., 1969). Yet, cocoon construction must reduce adult size and/or the requisites available for reproduction when the adult stage is reached. Despite this interesting interaction, little information exists on the amount of energy or biomass that immature stages direct to cocoon synthesis.

This note supplements the detailed energy and nitrogen budgets presented by Wightman and Rogers (1978) for unsexed, immature alfalfa leafcutting bees (*Megachile rotundata* (F.) (Megachilidae)) and provides data on 1) cocoon and prepupal wet weights and 2) overwintering weight loss from the prepupal to the adult stage. The following questions are considered: 1) Is cocoon size related to prepupal size and, if so, what is the form of the relationship? Wightman and Rogers (1978) reported that the cocoon averaged 12.4% of cocoon and prepupal dry weight. However, Stephen and Torchio (1961) noted that small individuals frequently spin incomplete cocoons. Thus, the relationship between the weights may be sigmoidal rather than parabolic or linear as might be predicted. 2) Do the sexes differ in the proportion of body weight used in cocoon construction? If the relationship between cocoon and prepupal weight is parabolic, then males might be expected to use a greater proportion of body weight in cocoon construction. 3) How much weight is lost during the transition from pupa to adult and is weight loss related to size or sex of the immature, or to the time during the flight season when an individual is produced?

### MATERIALS AND METHODS

Nests were obtained from paper soda straws (5 mm diameter, 6.7 cm depth) from artificial wooden domiciles at two sites in northern Utah. Data comparing cocoon and prepupal weights were obtained from Greenville Farm, North Logan,

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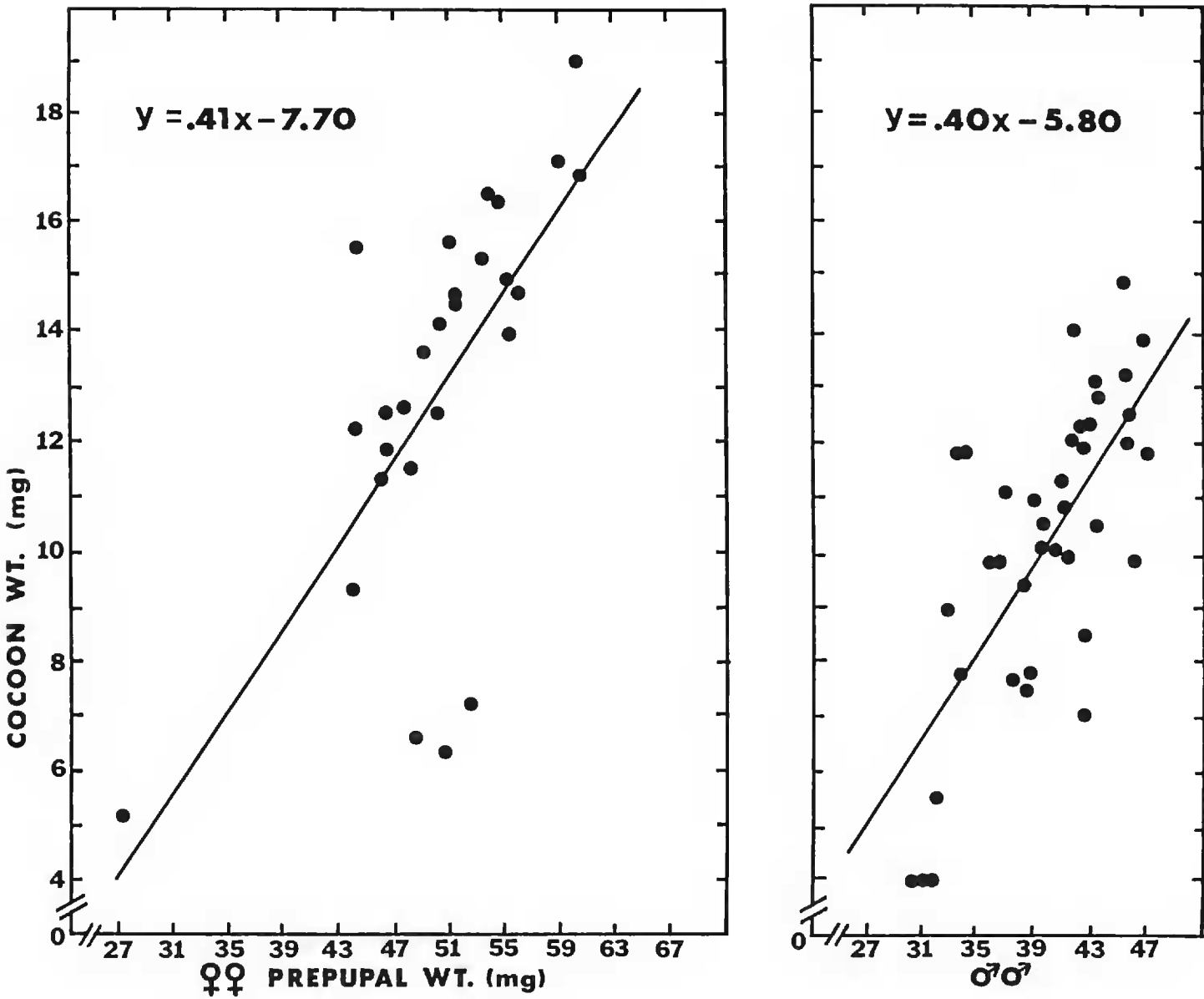


Figure 1. The relationship between weight of cocoon and weight of prepupae for female (a) and male (b) *M. rotundata*.

Utah (see Tepedino, 1983 for details). After collection in September, nests were maintained at room temperature (24–28°C) until mid-October when they were opened and separated into their component cells. Leaf pieces and feces were carefully removed from the cocoons of 100 randomly selected cells and cocoon and resident prepupa were weighed on an electronic balance (mg<sup>-1</sup>). Prepupae were stored in individual gelatin capsules at 4–5°C for the overwintering period. They were incubated at 29°C the following June and sex and mortality were recorded. Nests for the study of overwintering weight loss were obtained from a population housed adjacent to a commercial alfalfa field in Clarkston, Utah. Completed nests were collected weekly from mid-July through September and maintained in the laboratory at room temperature. In mid-October, 100 randomly selected cells from each collection date were opened and the prepupae weighed (mg<sup>-1</sup>). Subsequent treatment was as described above except individuals were weighed again upon emergence the following June.

RESULTS

The correlation between cocoon and prepupal weights was highly significant for both sexes ( $r(\delta) = 0.71$ ,  $n = 39$ ,  $P < 0.001$ ;  $r(\varphi) = 0.67$ ,  $n = 27$ ,  $P < 0.001$ ), and was best described by linear equations (Fig. 1). There was no significant

Table 1. Overwintering weight loss of male and female alfalfa leafcutting bees by week of collection. *n* = sample size, SD = standard deviation.

Week	Male			Female		
	<i>n</i>	% loss	SD	<i>n</i>	% loss	SD
1 (7/14)	23	4.1	2.5	10	5.4	4.4
2 (7/21)	67	3.4	2.4	35	4.2	3.7
3 (7/29)	80	5.2	2.8	25	5.4	3.5
4 (8/5)	34	5.0	4.4	11	4.0	3.6
5 (8/18)	60	3.3	1.1	14	3.6	1.2
6 (8/25)	56	4.5	3.7	18	3.4	1.4
7 (9/2)	57	5.6	1.7	18	5.9	4.1
8 (9/9)	69	4.2	2.2	20	3.6	0.9
9 (10/1)	21	1.9	1.4	10	3.1	3.8
ξ	467	4.3	2.8	161	4.4	3.2

difference between the sexes in the slopes of the regression lines ( $P > 0.05$ ). Combining data for both males and females yielded the equation:  $y = 0.33x - 3.10$  where  $y$  and  $x$  are cocoon and prepupal weights, respectively ( $r = 0.74$ ,  $P < 0.001$ ). In addition, there was no significant difference between the sexes in the ratio of cocoon weight to cocoon plus prepupal weight ( $x(\delta) = 0.201$ ,  $SD = 0.038$ ;  $x(\varphi) = 0.202$ ,  $SD = 0.037$ ;  $P > 0.05$ ).

Data on overwintering weight loss were subjected to arcsin transformation and analyzed by two-way unbalanced factorial ANOVA with sex and week of production as factors (Table 1). There was no significant difference between the sexes ( $P > 0.05$ ) nor was there a significant interaction between sex and weeks ( $P > 0.05$ ). There was, however, a significant difference among weeks ( $P < 0.001$ ); the only clear pattern was that prepupae produced during the last collection week lost less weight over winter than did those from other collection dates.

DISCUSSION

The estimate of cocoon weight as a percentage of cocoon and prepupal weight (20.1%) is substantially higher than that calculated from the data of Wightman and Rogers (1978) (12.4%). Their data are probably more accurate because dry weights rather than wet weights were used. It was impossible to use dry weight in this study because of the need to determine the sex of the specimens. Nevertheless, it is unlikely that the differences between the studies are due to the accuracy of measurement. Rather, populations of *M. rotundata* may differ in the energy and nutrients they invest in cocoons. In some species of bees, cocoon spinning appears to be facultative rather than obligatory, while in others, some individuals in a population spin cocoons but others do not (Rozen, 1984; Torchio and Trostle, 1986).

The only comparable data on cocoon and immature weights in non-social bees appears to be that of Parker (1984) for the megachilid bees, *Osmia latisulcata* Michener and its parasite, *Stelis depressa* Timberlake. In *S. depressa*, the cocoon represents 19.1% of cocoon and prepupal weight. For *O. latisulcata*, it was necessary to adjust Parker's (1984) measurements because he weighed adults rather than post-spinning prepupae. We used the overwintering weight loss estimate of

4.3% for *M. rotundata* to increase the adult weights reported by Parker (1984). After this adjustment, the estimate of cocoon weight as a percentage of cocoon and prepupal weights is 27.5% for males and 21.3% for females. The estimates for *O. latisulcata* are actually somewhat lower than those presented here because the cocoon weight includes weight of the feces. Thus, in both species, cocoon weight as a percentage of immature weight appears to be similar to that of *M. rotundata*. It would be instructive to know the relative amounts of calories or biomass that other species channel to cocoon construction and to relate this to other parameters such as incidence of parasitism, overwintering mortality and fecundity. Such comparisons await additional studies.

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